

Scheduling of Automated Guided Vehicles in Flexible Manufacturing Systems environment

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE IN**

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Mechanical Engineering

By

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CERTIFICATE

This is to certify that the thesis entitled, “Scheduling of Automated Guided Vehicles in Flexible Manufacturing Systems environment” submitted by Atul Tiwari in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela (Deemed University), is an authentic work carried out by him under my supervision.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Automated Guided Vehicles (AGVs) are among various advanced material handling techniques that are finding increasing applications today. They can be interfaced to various other production and storage equipment and controlled through an intelligent computer control system. FMS are well suited for simultaneous production of a wide variety of part types in low volumes. The FMS elements can operate in an asynchronous manner and the scheduling problems are more complex. The use of Automated Guided Vehicle is increasing day by day for the material transfer in production lines of modern manufacturing plants. The purpose is to enhance efficiency in material transfer and increase production. Though the hardware of AGV's has made significant improvement in the field but the software control of the fleet still lacks in many applications. Both the scheduling of operations on machine centers as well as the scheduling of AGVs are essential factors contributing to the efficiency of the overall flexible manufacturing system (FMS). In this work, scheduling of job is done for a particular type of FMS environment by using an optimization technique called the genetic algorithm (AGA). A 'C' programming code was developed to find the optimal solution. When a chromosome is input, the GA works upon it and produces same no. of offsprings. The no. of iterations take place until the optimum solution is obtained. Here we have worked upon eight problems, with different no. of machines and no. of jobs. The input parameters used are Travel Time matrix and Processing Time matrix with the no. of machines and no. of jobs. The results obtained are very quite close to the results obtained by other techniques and by other scholars.

INTRODUCTION

CHAPTER 1

Introduction:

The primary goals of today's automation technology are productivity and flexibility, which can only be achieved in fully integrated manufacturing environments. In this required integration a carefully designed and efficiently managed material handling system is of crucial importance. Automated guided vehicles (AGVs) are among the fastest growing classes of equipment in the material handling industry. They are battery-powered, unmanned vehicles with programming capabilities for path selection and positioning. They are capable of responding readily to frequently changing transport patterns, and they can be integrated into fully automated intelligent control systems. Automated guided vehicles (AGVs) are being increasingly used for material transfer in production lines of modern manufacturing plants. The purpose is to enhance efficiency in material transfer and increase production. However, while the hardware of AGVs has improved steadily, the software for the control of a fleet of AGVs in such applications still lack in many respects.

On the one hand there is need for finding optimal routes between pairs of source and receiving units. On the other hand, there remains the difficult task of assigning material transfer jobs to different AGVs and time them appropriately to reduce possible conflicts in path sharing and deadlocks. The most general requirement in an AGV application is the transfer of materials from a set of source units to a set of destination units. The source and destination units may be from the same pool of units as in the case of machining units processing components in a sequential manner. Otherwise they may be distinct, e.g. when the source units are the ones through which raw materials are fed, destination units receive the raw materials for complete machining. All raw materials are fed from the same station-we call it a loading point (LP). This loading point serves as the fixed source in our material transfer problem. The materials are transferred to a number of machining units, which serve as the delivery points (DP). The processed materials from these machining units are output to a separate AGV system whose area of operation is

physically disjoint with the area of operation of our AGVs. In other words, we are only concerned about the distribution of raw materials from LP to various DPs in a way that leads to optimal utilization of the machining units and the AGVs. In material distribution problem, the routes from LP to DPs are laid out like a tree with the LP at the root and DPs on the branches or at the leaves of the tree. Because there are no closed loops, there are no choices about moving from the LP to any of the DPs, or from one DP to another. So the routing problem is very much simplified in this case. We have data about the average consumption rates of materials at each DP. From sensors mounted on the conveyors, we know the stock position of each DP at any point of time. We assume a certain load capacity of the AGV. Our motive in analyzing an AGV based material distribution system suited to application is the following:

- (a) Find out minimum how many AGVs will be necessary to meet the entire material distribution requirement.
- (b) Propose and assess various dispatch rules for assigning transfer jobs to the AGVs. We input parameters that enable us to compare performances of different dispatch rules in terms of material throughput and evenness of distribution over the DPs.
- (c) Then a scheme is proposed for partitioning out the entire area into exclusive zones, one for each AGV—to reduce the path sharing among AGVs and thus avoid complications arising out of that.

Here an attempt has been made to consider simultaneously the machine and vehicle scheduling aspects in an FMS and address the problem for the minimization of makespan. Scheduling is concerned with the allocation of limited resources to tasks over time and is a decision making process that links the operations, time, cost and overall objectives of the company.

Applications of AGV's are in the following fields:-

- Aerospace
- Automotive
- Clean room
- Food and beverage
- Mail processing
- Manufacturing
- Newsprint
- Pharmaceuticals
- Plastics
- Warehouse

LITERATURE REVIEW

CHAPTER 2

Literature Review:

Most of the earlier works address the machine and vehicle scheduling as two independent problems. However, only a few had emphasized the importance of simultaneous scheduling of machines and vehicles. The high investment required for FMS and the potential of FMS as a strategic competitive tool make it an attractive research subject. Hence, a number of approaches and procedures are applied for scheduling the FMS. Scheduling of FMS has been extensively investigated over the last four decades, and it continues to attract the interest of both the academic and industrial sectors. Various types of scheduling problems are being solved in different job shop environments. A variety of many algorithms are employed to obtain optimal or near optimal schedules. Traditionally, the automatic generation of scheduling plans for job shops has been addressed using optimization and approximation approaches. Two basic approaches to this same problem are real-time scheduling and off-line scheduling. Both aspects are studied by several researchers. Fonseca and Fleming [1] proposed a multi-objective genetic algorithm (MOGA). Their approach consists of schemes in which the rank of an individual corresponds to the number of individuals by which it is dominated. Based on suggestions given by Goldberg's, Srinivas and Deb [1] developed an approach which was called non-dominated sorting genetic algorithm (NSGA). These non-dominated solutions of a front are assigned the same dummy fitness value and are shared with their own dummy fitness values and ignored in the further classification process. Finally, the dummy fitness is set to a particular value less than the smallest shared fitness value in the current one of the non-dominated front. Then the next front is extracted and the process is repeated until all the individuals in the population are classified. Wu and Wysk[2], Ro and Kim[19], Sabuncuoğlu and Hommertzheim[17], and Sawik[14] develop on-line dispatching and control rules for machines and AGVs. The case of a special material handling transporter in a real time environment is treated by Han and McGinnis[4]. Taghaboni and Tanchoco[3] develop

an intelligent real-time controller for free-ranging AGVs. Tanchoco and Co[20] introduce real-time control strategies for multiple-load AGVs.

Karabtk and Sabuncuo~lu [3] introduce a beam search based algorithm for the simultaneous scheduling of machines and AGVs. A deterministic off-line scheduling model formulated as an integer programming problem and a solution procedure based on concepts of project scheduling under resource constraints are presented by Raman et al[2]. Their assumption that vehicles always return to the load/unload station after transferring a load reduces the flexibility of the AGV and its influence on the schedule.

Lacomme et al. [4] has addressed the simultaneous job input sequence and also vehicle dispatching for a single AGV system. They solved this problem using the branch and bound technique coupled with a discrete event simulation model. Multi-objective optimization has always been a subject of interest to researchers of various backgrounds since 1970 and considerable attention has been received by genetic algorithms as a novel approach to the multiobjective optimization problems. Schaffer [12] has presented a multi-modal EA called vector evaluated genetic algorithm (VEGA), which carries out selections for each objective separately. An approach based on this weighted sum scalarization was introduced by Hajela and Lin [15] to search for multiple solutions in parallel.

Blazewicz et al [14] consider an FMS with parallel identical machines arranged in a loop. Pandit and Palekar [15] present a number of variants of a shifting bottleneck heuristic for minimizing makespan with a single vehicle. Another off-line model for makespan minimization is presented by Bilge and Ulusoy[16] who investigate the problem for multiple AGVs. They formulate the problem as a mixed integer programming problem. In this formulation, the AGVs don't have to return to the load/unload station after each delivery which increases the complexity of the problem. The overall problem is decomposed into two sub problems, and an iterative solution procedure is developed. Anwar and Nagi[4] addressed the simultaneous scheduling of material handling operations in a trip-based material handling system and

machines in JIT environment. Abdelmaguid et al. [16] has presented a new hybrid genetic algorithm for the simultaneous scheduling problem for the makespan minimization objective. The hybrid GA is composed of GA and a heuristic. The GA is used to address the first part of the problem that is theoretically similar to the job shop scheduling problem and the vehicle assignment is handled by a heuristic called vehicle assignment algorithm (VAA). Horn et al. [12] proposed the niched Pareto GA that combines tournament selection and the concept of Pareto dominance. Zitzler and Thiele [19] have proposed the strength Pareto evolutionary algorithm (SPEA). They maintained an external archive which store all the non-dominated solutions found at every generation from the beginning. The archive solutions are allowed to participate in the genetic operations which lead to quick convergence of the algorithm. Knowles and Corne [10] developed an approach called Pareto archived evolution strategy (PAES) that incorporates elitism. In their approach, non dominance comparison was made between a parent and the child.

FMS AND SCHEDULING

CHAPTER 3

Flexible Manufacturing System:

In the present day, automated manufacturing environment, FMS are agile and provide wide flexibility. FMS are well suited for simultaneous production of a wide variety of part types in low volumes. FMS is a complex system consisting of elements like workstations, automated storage and retrieval systems, and material handling devices such as robots and AGVs. The FMS elements can operate in an asynchronous manner and the scheduling problems are more complex. Moreover, the components are highly interrelated and in addition contain multiple part types, and alternative routings etc. FMS performance can be increased by better co-ordination and scheduling of production machines and material handling equipment.

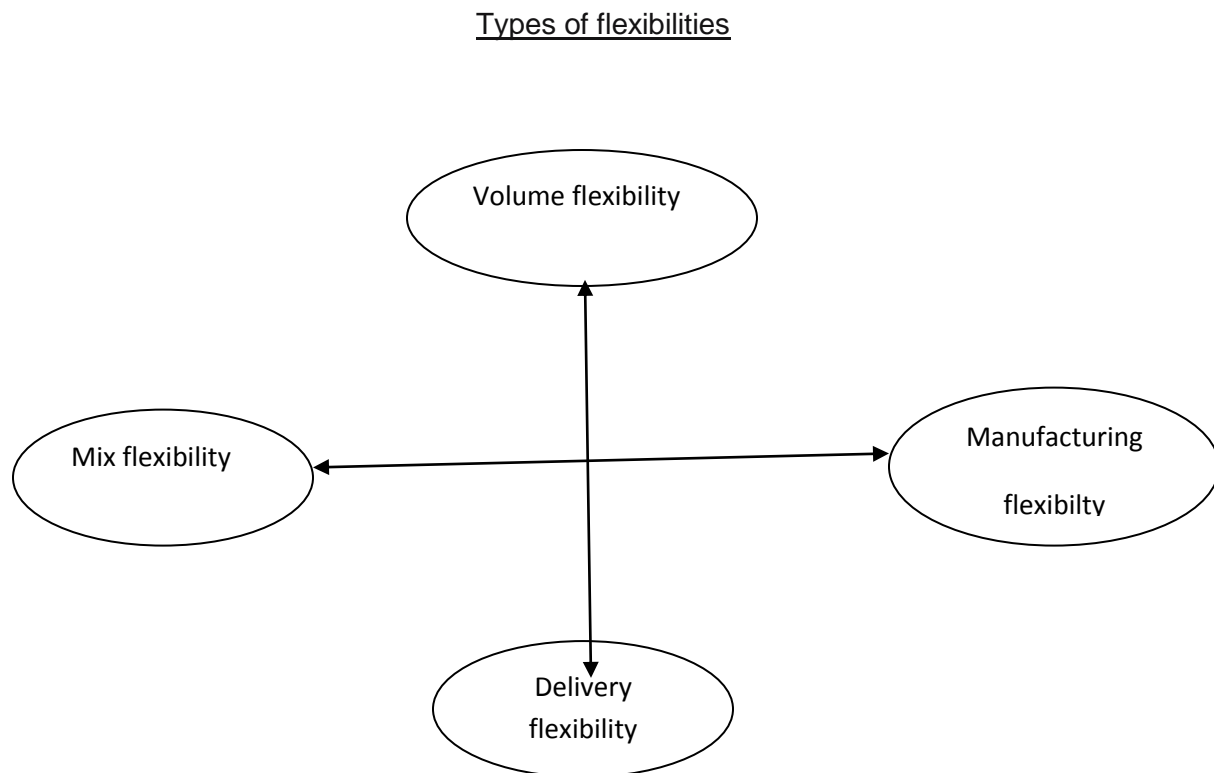


Fig. 1

An Industrial Flexible Manufacturing System (FMS) mainly consists of robots, Computer-controlled Machines, Numerical controlled machines (CNC), instrumentation devices, computers, sensors, and other stand alone systems such as inspection machines. The use of robots in the production segments of manufacturing industries gives a wide variety of benefits ranging from high utilization to high volume of productivity. Each Robotic cell or node will be located along a material handling system, such as a conveyor or AGV. The production of each part or work-piece will require a very different combination of manufacturing nodes. The movement of various parts from one node to another is done through a the material handling system. At the end of part processing, the finished parts are routed to an automatic inspection node, and subsequently unloaded from the Flexible Manufacturing System. Advantages of FMS are faster and lower cost changes from one part to another, lower direct labor cost, reduced inventory, consistent and better quality, and lower cost/unit of output.

Scheduling and AGVs:

An AGV is nothing but a mobile robot that follows wires or markers on the floor, or uses vision or lasers. They are most often used in industrial application to move various materials around a manufacturing facility or a ware house. An AGV is also known as laser Guided Vehicle (LGV) or Self Guided Vehicle (SGV). Lower cost version of AGVs is often termed as Automatic Guided Vehicle (AGCs) and is usually guided by magnetic tape. Scheduling is concerned about the allocation of limited resources to tasks over time and is also a decision making process that links the various operations, time, cost and overall objectives of the company. Scheduling of machines, other resources such as vehicles, personnel, tools etc., has been done with a certain objective, to be either minimized or maximized. Some of these objectives include minimization of makespan, tardiness, earliness, in-process- inventory (WIP) etc. Typically, parts in a manufacturing system often visit different machines for different operations, and they thus generate demands for the material handling devices. Scheduling of the material handling system in FMS has an equal importance as of machines and is to be considered together for the actual evaluation of cycle times. Automated guided vehicles (AGVs) are widely used in FMS due to their flexibility and compatibility. AGVs can be integrated with the computer controlled production and storage equipment in the shop floor and hence the entire shop floor operations can be controlled through a computer system. Most of the real world-scheduling problems involve simultaneous scheduling of machines and transportation equipment. In this work, particle swarm optimization (PSO) or Genetic algorithm can be applied for solving scheduling problem in FMS.

METHODOLOGY

CHAPTER 4

Operation and control flow:

A centralized processor monitors the material stock status of each DP conveyor. When the material stock at a DP falls below a pre-specified level, it becomes eligible to receive materials. The central processor maintains a track of such eligible DPs along with their current stock positions, so as soon as any AGV becomes available for service, it decides which DPs should be served first, based on the prevailing dispatch rules. It can also determine the sequence in which the chosen DPs may be visited to minimize the travel time. Accordingly it generates a transfer order for the AGV to execute. A transfer order may contain a chain of nodes to be visited by the AGV. At some of these nodes, the AGV has to stop to load or unload materials.

Armed with the transfer order, the AGV reaches the LP where it loads the required materials for delivery to the selected DPs. After reaching there, it unloads the appropriate loaded bins, and loads empty bins. After all loaded bins are delivered and empty bins are picked up, the latter are unloaded to an empty bin unloading station close to the same LP. This completes one AGV trip.

Dispatch rules:

Time-stock of a DP indicates that the time it will take for its stock to vanish if no further supply comes in. If the present stock-level of any DP is 'x' units, its time-stock will be given by,

$$T = x/k,$$

Where k is the consumption rate of that DP.

Time-stock can either be both positive and negative. A negative time-stock indicates the time elapsed since the stock fell to zero. Priority of a DP is the negative of its time-stock. We set a specific value for this time-stock of a DP below which the DP becomes eligible to receive the material. The case is then admitted by the Dispatch Rule while deciding on which DPs may be served by the AGV as it starts the next trip. It is set such that the conveyor capacity is not exceeded in case the AGV delivers to this DP at its current stock level. The single destination travel, in short SD-travel, of a DP is the distance covered by the AGV to complete a trip from LP to the DP and back to LP. In case of multiple destination (MD) dispatch rules, we shall also talk about MD-travel, the distance an AGV would cover to visit the selected DPs in the desired order and return to the LP.

These dispatch rules decide which DPs may be served by the AGV as it starts its next trip. They strongly influence the throughput and evenness of material distribution. Two different kinds of dispatching are considered here:

- (1) **Single Destination (SD)**: This rule says, that we should feed the entire capacity of the AGV to the DP which has the highest priority for service by the AGV. All the stacks of the plastic bins onboard the AGV can carry the same material and are deliverable at that single DP.

(2) **Multiple Destinations (MD)**: This rule says that the AGV will feed more than one DP (this number is same as the no. of conveyor bays onboard the AGV. Four rules are considered here:

- MD1

AGV selects three DPs in order of their priority and feed them in the same trip splitting its capacity into three parts, one for each DP. The DPs are visited in an order in which MD-travel is minimum.

- MD2

Here, AGV selects three DPs, such that the first DP is the one with highest priority, while the second and the third are selected among eligible contenders to minimize the MD-travel.

- MD3

This is quite same as MD2 but with an added constraint that the top six eligible contenders only (in order of priority) are considered by the AGV.

- MD4

AGV selects an ordering for three DPs from top six eligible contenders (there are 6P3 such orderings) such that $(p * L)$ divided by MD-travel is maximized. Here 'p' is the priority and 'L' is the SD-travel of the selected DP. By weighting the priorities with SD-travel, this dispatch rule tries to remove the bias of MD2 and MD3 in favor of nearby DPs.

Role of GA in scheduling problem:

The genetic algorithm (GA) is a stochastic search procedure for combinatorial optimization problems based on the mechanism of natural selection and natural genetics. Essentially, a GA is a set of procedures that, when repeated, enables solutions for specific problems to be found. GAs generate successive populations of alternative solutions, until a solution that yields acceptable results is found. Individuals chromosomes are selected for reproduction, based on their fitness and the selected individuals, they undergo the genetic operations, crossover and mutation. Few of the existing chromosomes of the current population are replaced with the newly formed ones and this becomes the population for the next generation and this process is continued till the termination criterion is met. In this way a GA can quickly achieve a successful outcome without the need to examine every possible solution to the problem. The time required for computation is very important, but the present-day speed of the computers makes this process acceptable. The increasing performance of modern computer systems permits the application of new algorithms such as GA and simulated annealing, for production scheduling problems that required too much computing time in the past.

Algorithm for GA

Step1: Initial population is generated, (P_0).

Step2: Initial population (P_0) is evaluated.

Step3: If results satisfy the stopping condition, then stop or else repeat.

Step4: Elements from P_0 are selected to $P_0 + t$.

Step5: Elements of P_0 are crossover and are put into $P_0 + t$.

Step6: Mutate chromosomes of P_o and put into $P_o + t$.

Step7: New population is evaluated.

Step8: $P_o = P_o + t$.

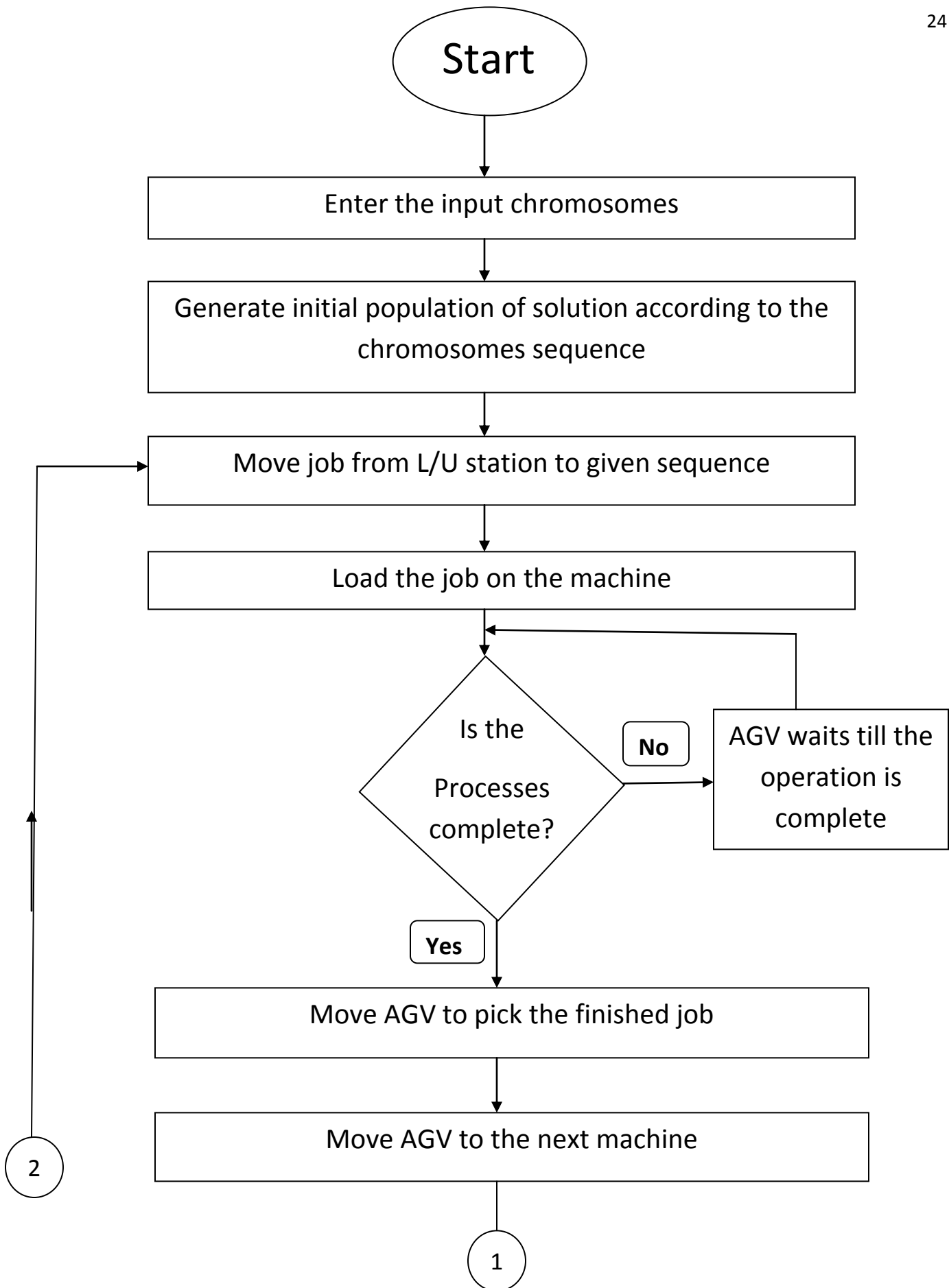
Representation

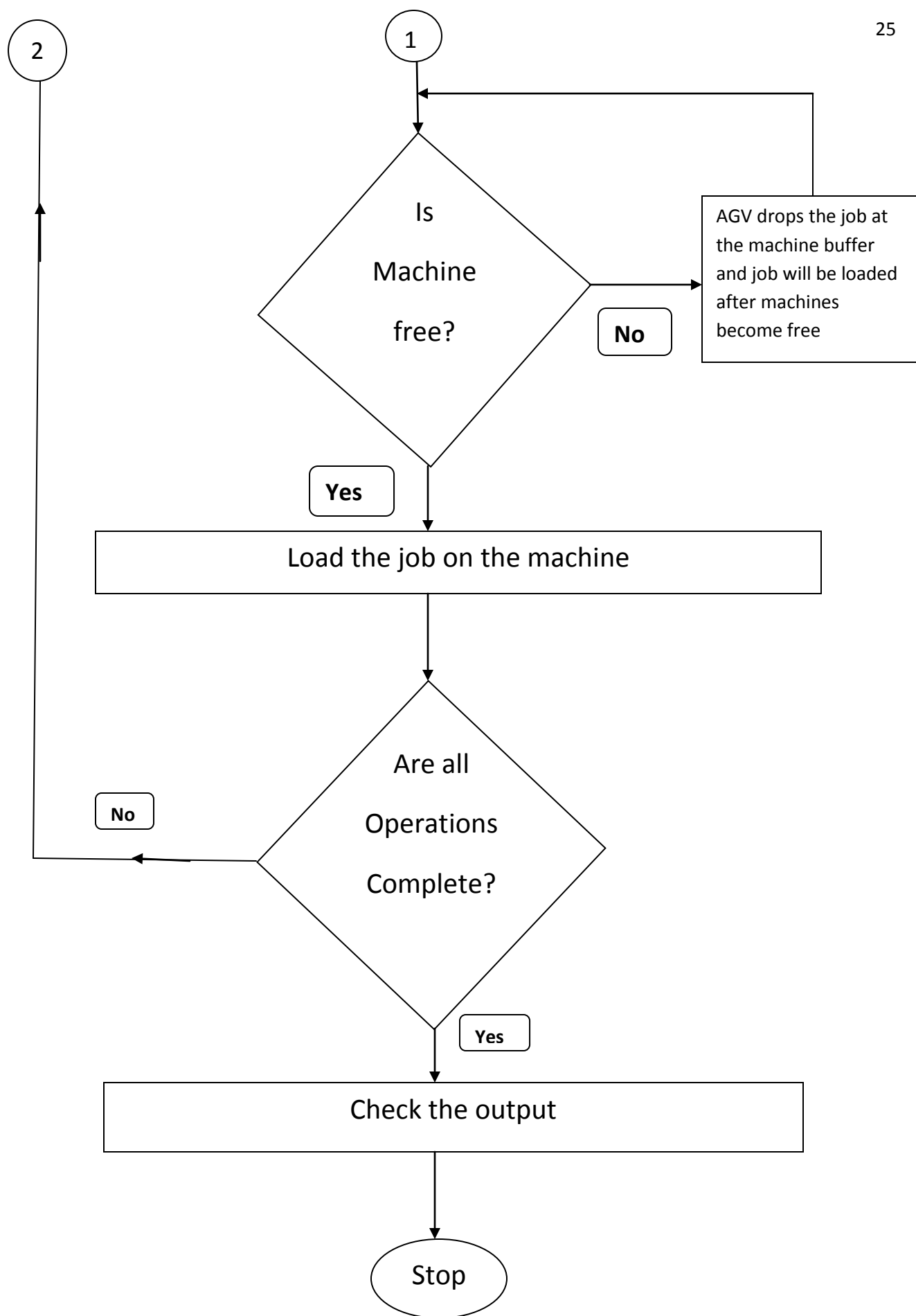
Table 1:

No. of jobs	1				2				3				4			
No. of Operations	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Machines	M1	M2	M3	M4	M1	M2	M3	M4	M1	M2	M3	M4	M1	M2	M3	M4
Representation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
One Feasible chromosome	3	2	7	9	16	1	12	14	8	15	13	6	10	5	4	

Here, the representation is done by keeping the job no. fixed and varying the machines serially. When all the processes of a job are finished, then the next job is represented serially and so on all the representation continues. Then we assign a chromosome and GA is followed to obtain the feasible chromosome after so many iterations.

The flowchart for the genetic algorithm procedure is as follows:





PROBLEM FORMULATION

CHAPTER 5

Problem Formulation:

Typical operational, planning and control problems that have to be handled are:

- Defining nodes and track-segments on the floor, with given no. of the LP, DPs, and accessible areas for vehicle movement,
- Assessing the number requirement of AGVs to meet the specified consumption rates at the DPs,
- Defining parameters to evaluate and compare system performance under various dispatch rules,
- Defining dispatch rules for the AGVs. A dispatch rule lays out a procedure, to decide which DPs may be served, on the basis of current stock positions.
- Routing of AGVs is done to ensure that they are utilized in an efficient manner. After the DP selection is over, routing decides in which sequence the selected DPs may be visited.
- If there are a number of AGVs, they must obey some protocols for travelling over shared track segments, to avoid getting into a deadlock situation. Here we subscribe to a decentralized control strategy, rather than a time-window constrained route planning strategy. This does not apply in our case, as there are no alternative routes available to plan a trip on the basis of time windows.

The FMS layout along with the distances between the machines and from the load/unload station are all shown for different problems. The FMS consists of given no. of machines and 2 AGV's. The job set details are also given. AGV move with a speed of 40 m/min and the loading and unloading times of job are 0.5 min each. The travel times are computed and are presented in Table, in which the loading and unloading times of the job are included.

Objective Criteria : Minimization of makespan.

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GA Parameters : Population size=300,
Archive size=300,
Probability of crossover=0.6,
Probability of mutation=0.4,
Number of generations=100.

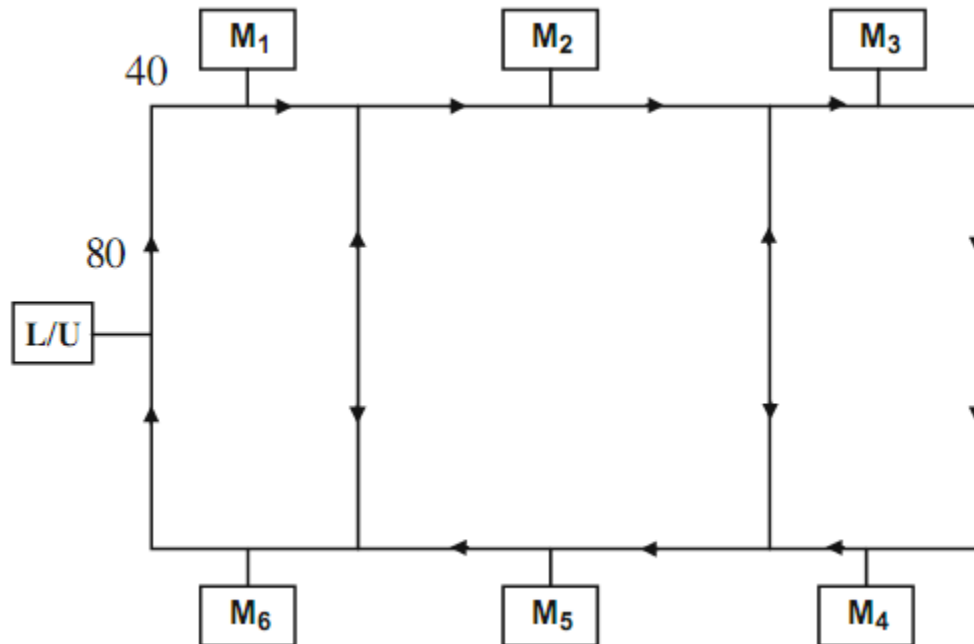
Problem 1:

Fig 2

No of machines: 6

No of jobs: 6

Travel Time matrix:

Table 2:

	L/U	M1	M2	M3	M4	M5	M6
L/U	0	4	6	8	14	12	10
M1	10	0	3	5	11	9	7
M2	12	15	0	3	9	7	9
M3	14	17	15	0	7	9	11
M4	8	11	9	7	0	3	5
M5	6	9	7	9	15	0	3
M6	4	7	9	11	17	15	0

Processing Time Matrix:

Table 3:

Job No.	M/C	PT	M/C	PT	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	3	2	6	3	1	4	7	5	6	6	3
2	1	10	2	8	3	5	4	4	5	10	6	10
3	1	9	2	1	3	5	4	4	5	7	6	8
4	1	5	2	5	3	5	4	3	5	8	6	9
5	1	3	2	3	3	9	4	1	5	5	6	4
6	1	10	2	3	3	1	4	3	5	4	6	9

Total makespan time sum of all the processing and travelling time.

Sequence of the process:

Chromosome is 1 13 19 7 8 14 2 3 21 15

Makespan Time is: 116 mins

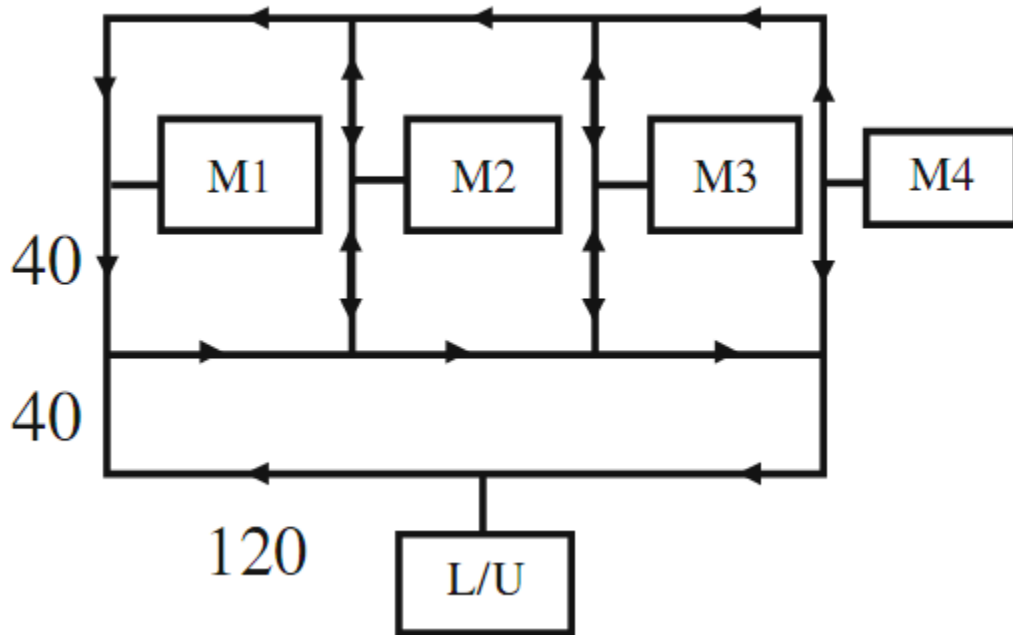
Problem 2:

Fig. 3

No. of machines: 4

No. of jobs: 4

Travel Time matrix:

Table 4:

	L/U	M1	M2	M3	M4
L/U	0	6	8	10	14
M1	12	0	6	8	10
M2	10	6	0	6	8
M3	8	8	6	0	6
M4	6	10	8	6	0

Processing Time Matrix:

Table 5:

Job No.	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	3	2	6	3	1	4	7
2	1	10	2	8	3	5	4	4
3	1	9	2	1	3	5	4	4
4	1	5	2	5	3	5	4	3

Sequence of the process:

Chromosome is 5 16 2 8 12 10 14 1 6

Makespan Time is: 104 mins

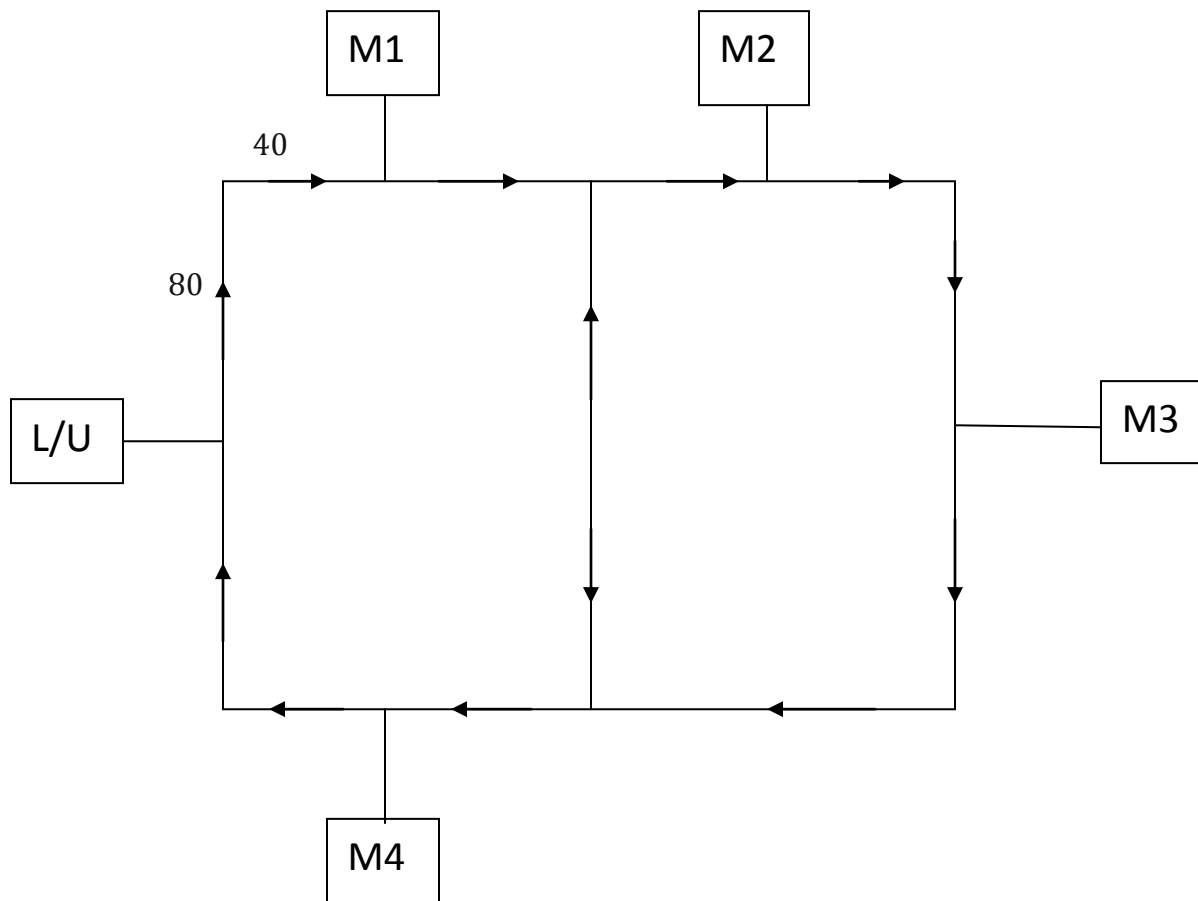
Problem3:

Fig. 4

No. of machines: 4

No. of jobs: 4

Travel Time matrix:

Table 6:

	L/U	M1	M2	M3	M4
L/U	0	4	6	9	10
M1	10	0	3	6	4
M2	12	15	0	4	9
M3	9	12	10	0	6
M4	4	7	9	12	0

Processing Time Matrix:

Table 7:

Job No.	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	4	2	6	3	7	4	8
2	1	5	2	7	3	3	4	3
3	1	1	2	3	3	9	4	4
4	1	2	2	8	3	3	4	2

Sequence of the process:

Chromosome is 3 16 9 12 13 7 9 2 8

Makespan Time is: 86 mins.

Problem 4:

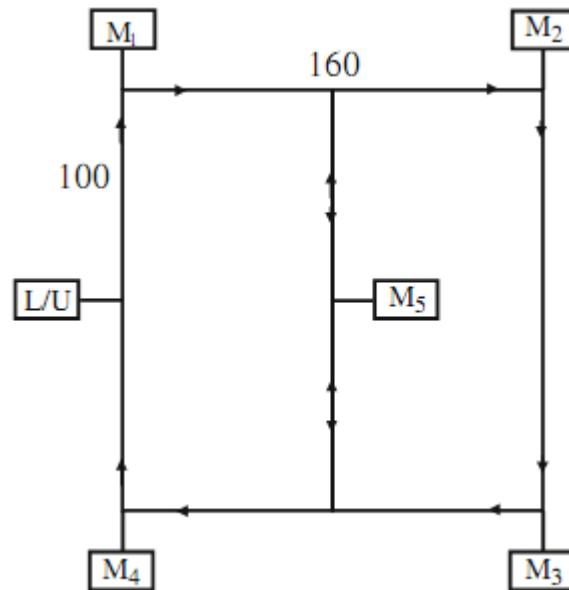


Fig. 5

No. of machines: 5

No. of jobs: 5

Travel Time matrix:

Table 8:

	L/U	M1	M2	M3	M4	M5
L/U	0	4	8	13	13	8
M1	14	0	5	10	10	6
M2	13	15	0	6	10	11
M3	8	10	10	0	5	6
M4	4	6	10	15	0	11
M5	8	12	6	11	6	0

Processing Time Matrix:

Table 9:

Job No.	M/C	PT	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	5	2	3	3	3	4	6	5	6
2	1	10	2	2	3	5	4	4	5	10
3	1	4	2	6	3	6	4	2	5	4
4	1	6	2	8	3	5	4	6	5	1
5	1	7	2	2	3	2	4	1	5	9

Sequence of the process:

Chromosome is 22 3 6 12 16 18 25 13 1 19

Makespan Time is: 133 mins

Problem 5:

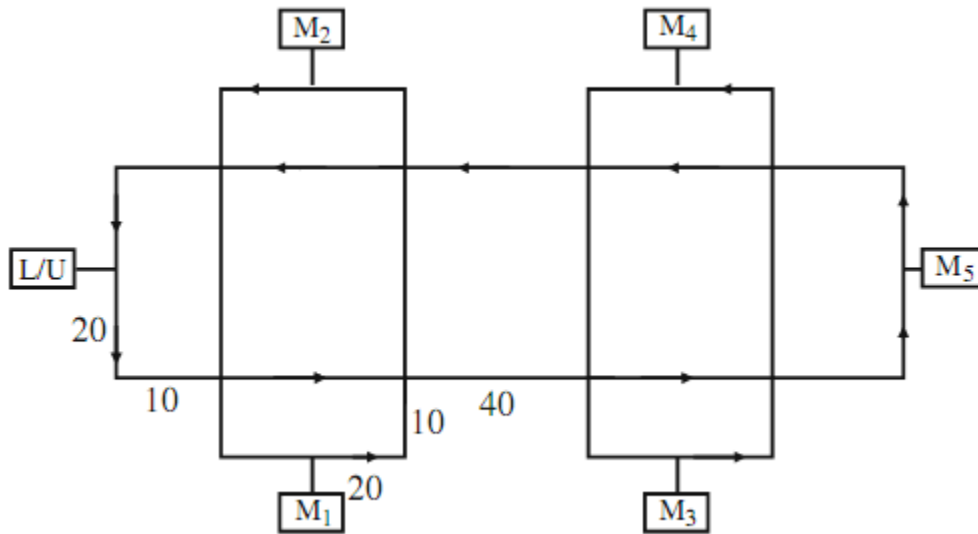


Fig. 6

No. of machines: 5

No. of jobs: 5

Travel Time matrix:

Table 10:

	L/U	M1	M2	M3	M4	M5
L/U	0	3	5	5	7	6
M1	5	0	4	4	6	5
M2	3	4	0	6	8	7
M3	7	8	6	0	4	3
M4	5	6	4	4	0	5
M5	6	7	5	5	3	0

Processing Time Matrix:

Table 11:

Job No.	M/C	PT	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	5	2	3	3	2	4	2	5	1
2	1	3	2	2	3	5	4	7	5	10
3	1	2	2	6	3	1	4	2	5	6
4	1	2	2	8	3	5	4	1	5	3
5	1	4	2	2	3	6	4	9	5	9

Sequence of the process:

Chromosome is 12 17 13 19 1 4 23 9 24 18

Makespan Time is: 93 mins

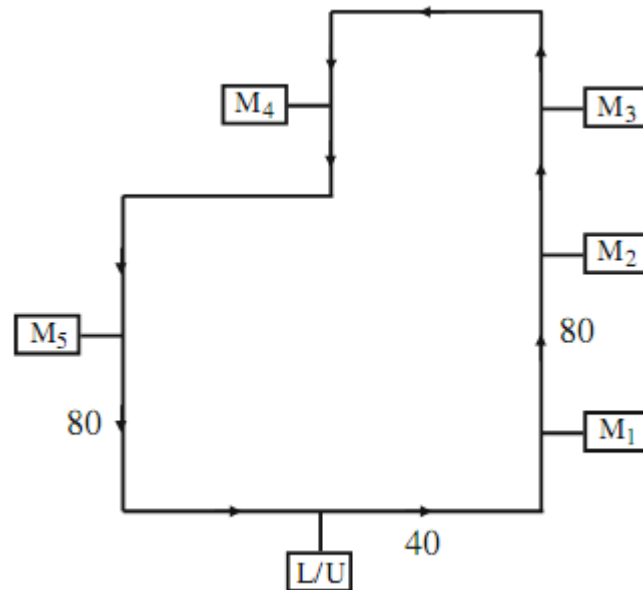
Problem6:

Fig. 7

No. of machines: 5

No. of jobs: 5

Travel Time matrix:

Table 12:

	L/U	M1	M2	M3	M4	M5
L/U	0	3	5	7	9	14
M1	15	0	3	5	8	12
M2	13	15	0	3	6	10
M3	11	13	15	0	4	8
M4	7	9	11	13	0	5
M5	4	6	8	10	13	0

Processing Time Matrix:

Table 13:

Job No.	M/C	PT	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	4	2	5	3	8	4	8	5	1
2	1	5	2	7	3	3	4	3	5	2
3	1	1	2	6	3	9	4	2	5	6
4	1	2	2	8	3	3	4	5	5	3
5	1	4	2	1	3	1	4	7	5	4

Sequence of the process:

Chromosome is 17 12 8 21 12 7 18 10 1 9 15

Makespan Time is: 162 mins.

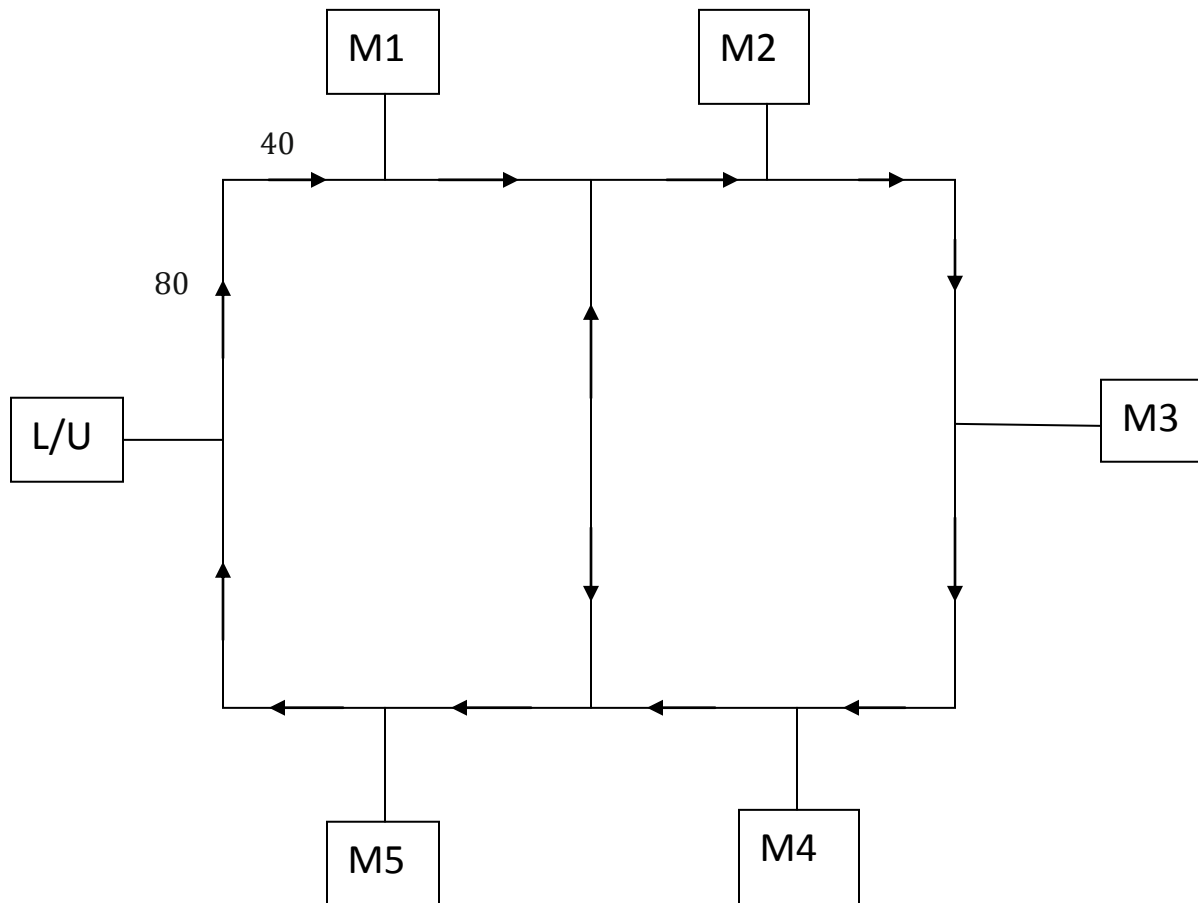
Problem7:

Fig. 8

No. of machines: 5

No. of jobs: 5

Travel Time matrix:

Table 14:

	L/U	M1	M2	M3	M4	M5
L/U	0	4	6	9	12	10
M1	10	0	3	6	9	7
M2	12	15	0	4	7	9
M3	9	12	10	0	6	6
M4	6	9	7	10	0	3
M5	4	7	9	12	15	0

Processing Time Matrix:

Table 15:

Job No.	M/C	PT	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	4	2	5	3	8	4	8	5	1
2	1	5	2	7	3	3	4	3	5	2
3	1	1	2	6	3	9	4	2	5	6
4	1	2	2	8	3	3	4	5	5	3
5	1	4	2	1	3	1	4	7	5	4

Sequence of the process:

Chromosome is 2 14 25 7 13 9 12 18 3 17 4

Makespan Time is: 139 mins.

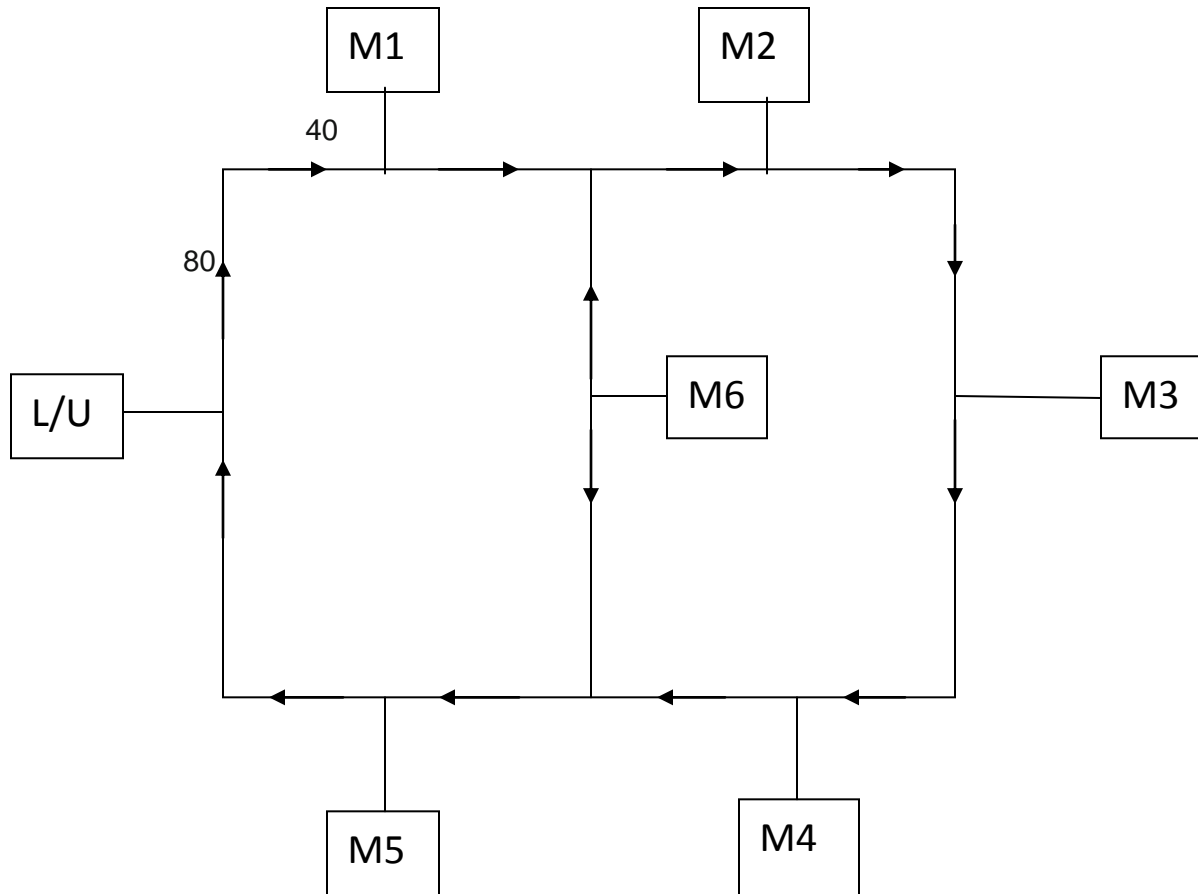
Problem8:

Fig. 9

No of machines: 6

No of jobs: 6

Travel Time matrix:

Table 16:

	L/U	M1	M2	M3	M4	M5	M6
L/U	0	4	6	9	12	10	7
M1	10	0	3	6	9	7	4
M2	12	13	0	4	7	9	10
M3	9	12	10	0	4	6	7
M4	6	9	7	10	0	3	4
M5	4	7	9	12	15	0	10
M6	7	10	12	15	18	4	0

Processing Time Matrix:

Table 17:

Job No.	M/C	PT	M/C	PT	M/C	PT	M/C	PT	M/C	PT	M/C	PT
1	1	5	2	4	3	2	4	5	5	9	6	8
2	1	10	2	8	3	5	4	4	5	10	6	10
3	1	9	2	4	3	5	4	3	5	7	6	8
4	1	5	2	5	3	5	4	3	5	8	6	8
5	1	3	2	2	3	9	4	1	5	5	6	2
6	1	10	2	3	3	1	4	4	5	4	6	7

Sequence of the process:

Chromosome is 34 26 12 7 1 8 36 14 28 30 3

Makespan Time is: 129mins

RESULTS and DISCUSSIONS

CHAPTER 6

Results and Discussions:

The result of the various problems discussed above is shown here in the table. The problems are categorized as small size problems (SS) involving upto 50 operations, medium size problems (MS) upto 100 operations, and large size problems (LS) involving above 100 operations. In most of the test cases the results were terminated before 150 generations for the probabilities of crossover and mutation as 0.6 and 0.4, respectively. The designed scheduling procedure with the genetic algorithm software was developed in C programming language to conduct experiments. While conducting trials it was found that the procedure was well able to achieve the objective.

Table 18:

Problem No.	No. of Machines	No. of Jobs	Makespan Time
1.	6	6	116
2.	4	4	104
3.	4	4	86
4.	5	5	133
5.	5	5	93
6.	5	5	162
7.	5	5	139
8.	6	6	129

CONCLUSION

CHAPTER 7

Conclusion:

In this work, 8 complex AGV problems are considered which are taken from different literatures. A 'C' programming code was developed to find out the makespan time of different jobs. The mechanism operates based on a genetic algorithm and optimizes the makespan time of the job. The results obtained from this are quite satisfactory and close to the values as solved by the other scholars. Very little variations in the result shows the accuracy of the above work.

Also, the solution being closer to other methodology shows the potential of Genetic Algorithm. By changing the evaluation parameter of the genetic search process, solutions can be obtained for other suitable objectives and can be made more flexible. The extensions to handle alternative route choices and to revise the schedules in real-time operations lead to significantly enhanced productivity.

Future Scope:

The problems here solved are solved by following Genetic Algorithm. It can also be solved by various other techniques such as particle Swarm Optimization and many others. Another approach can also be by following Adaptive Genetic Algorithm or by following higher Heuristic Approach. Generally, jobs are scheduled but simultaneous scheduling of jobs and machines remains the most interesting area to work on and this can do wonders to our industrial life. In this case, both, jobs and machines will work together and the makespan time can be drastically reduced.

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